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E X P L A N A T I O N

O F A N E W

CONSTRUCTION AND IMPROVEMENT

O F T H E

Sea Octant and Sextant,

CONTAINING,

A most easy, expeditious and accurate Method of
ADJUSTING and RECTIFYING those Instruments for
Use both at SEA and LAND. Also the best Disposition
of the GLASSES; with Directions for making the
Fore and Back Observations; and the several Steps
in the Process of finding the LONGITUDE at SEA.

ILLUSTRATED BY FOUR COPPER-PLATES.

By B. M A R T I N.

L O N D O N:
Printed for the Author, at No. 171, Fleet-Street.
(Price 1s. 6d.)

12. 11/10/59

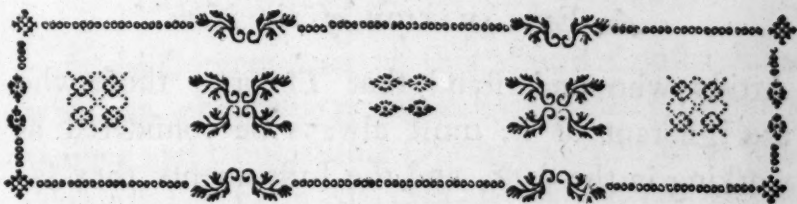
P R E F A C E.

NOtwithstanding the Public are indebted solely to my SON, J. L. MARTIN, for the Invention of this New Construction and Improvement of the Sea-Octant, yet when the Nature and Merits thereof are well considered and understood, I believe no ingenuous and intelligent Person will think I have exaggerated one Syllable in Favour of it thro' Prejudice or Partiality; to do JUSTICE to the Artifice, and to the Mariner (for whose Service it is intended,) I could not say less than I have done, to recommend it; what I have said being nothing more than barely to explain the Rationale of the Contrivance, which contains in itself the only Eulogium of its Usefulness. No one has yet seen it, but admires its Simplicity and Facility; and I think there can be no Doubt but that every one who prefers Ease and Expedition to an irksome Tedioufness in the RECTIFICATION of this noble Instrument, can hesitate one Moment concerning the Advantage that must accrue to the NAVIGATOR from this Improvement.

I have added a few Observations on the necessary Qualities of the Glasses; the Passage of Light between them; the Estimation of the Errors of the Fore and Back Observation; the concise THEORY of the OCTANT; and an Enumeration of all the Steps necessary to be taken in the Process of finding the LONGITUDE, by the Distance of the MOON from the SUN. And lastly, I have illustrated the Whole by a much greater Number of Diagrams (in four Copper-Plates) than have ever been published in Tracts on this Subject.

To conclude, I have thought this Improvement of Consequence enough to deserve the SANCTION of the ROYAL PATENT; and I make no Doubt but it will prove an acceptable Endeavour towards perfecting the ART of NAVIGATION. The Author of this, has also invented a NEW CONSTRUCTION of the AZIMUTH COMPASS without being confined in, and its Freedom of Motion checked by cumbersome Hoops, in which it is suspended; an Account of which may prove the Subject of an APPENDIX to this Tract ere long.





AN EXPLANATION OF A NEW
CONSTRUCTION AND RECTIFICATION
O F
HADLEY'S QUADRANT;
O R, T H E
S E A - O C T A N T.

I. * * * * * T H E P R I N C I P L E S of a S C I E N C E are
the only Means by which we can be
assisted in the I N V E N T I O N of I N -
S T R U M E N T S, and by which they
are rendered subservient to the various useful Pur-
poses of Life. Thus the Principles of O P T I C S have
suggested the I n v e n t i o n of the S E A - O C T A N T,
which must be allowed Precedence of all others,
and worthy of its illustrious Author, Sir I S A A C
N E W T O N.

2. It is true, no Instrument can be constructed
to the *Perfection* of its T H E O R Y; but the nearest
Approximation thereto can only be expected from

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Artists

Artists who understand that Theory; those who are ignorant of it, must always be considered as working in the dark, and the Instruments they fabricate, liable to Absurdities and Errors.

3. No Instrument was ever a greater Instance of the above-mentioned Truth than *Hadley's Quadrant*, as it is usually called, equally unlucky in its Construction and Explication, as any one may see in Mr. *Hadley's* original Account of it in the *Philosophical Transactions*, or Dr. *Smith's Optics*. Instead of the obscure, prolix and intricate Theory there given, it boasts the most concise and clearest possible; and instead of the usual, inartificial, opposite and tedious Construction, it admits of the most simple, expedite and easy, that can be desired; to demonstrate which, is the Subject of this Essay.

4. I have elsewhere given its whole Theory in *six Lines* only, from the Properties of a plain Triangle alone; these six may be reduced to *four*, as will be hereafter shewn; and is there any Instrument of a *mathematical Nature*, that can pretend to a *Rationale* so simple, so concise, so perspicuous?

5. As to the common Construction of the SEA-OCTANT, it is every Way unworthy of an Artist. One Consideration only is sufficient to evince this; viz. *That all the three Glasses are moveable*, whereas, *one only* of the three is required to be so. The THEORY forbidding any Motion at all in the two *Horizon Glasses* for the fore and back Observations.



6. In Consequence of this absurd Construction, what an unnecessary *Apparatus* of Parts; what a tedious and troublesome Operation; and what Uncertainty and Error will ever attend Observations by such an Instrument.

7. By making the Horizon Glasses moveable, a Disorder is occasioned in the Instrument, which the Maker is obliged to cure, or, rather to palliate, in the best Manner he can; for this Purpose he fixes the Base of each Glas upon two *moveable Points*; and then he is obliged to give them a two-fold Motion on these Points, *viz.* a *Motion of Inclination* to the Plane of the Quadrant, and a Motion about a Perpendicular thereto. The first of these is effected by two Screws and a Screw-driver; the second by a Lever, its Adjuster, and Fastening-Screw.

8. On Account of such a needless Multiplicity of Parts and Operations by them, the Adjustment of the Quadrant is rendered very difficult at Land, and absolutely impracticable at Sea. Nay, to such a miserable Shift is the poor Mariner reduced by this wretched Construction, that he is advised to find the Error of the Quadrant before he goes the Voyage, and to pocket the same for his Use at Sea. This is *helping the lame Dog over the Stile, with a Witness.*

9. But this is not all, the greatest Misfortune to the Navigator is the Imperfection of the Octant, arising from so faulty a Construction, by which he is rendered incapable of adjusting it at Sea, where and

when it is most of all wanted, and by an Object the best of all others for that Purpose, I mean, the Sun. How, such an essential Deficiency as this should escape the Notice of so good a Mathematician as Mr. CALEB SMITH, (whose Nautical Limb of 150 Degrees, is the best Instrument of this Sort, that I have seen), is very wonderful.

10. I shall proceed to explain and demonstrate the genuine Construction of so noble an Instrument from the THEORY, which has been already delivered in a Treatise given with the Quadrant. Let A, B, C, represent the Quadrant. D, E, F, the three Glasses, and H, I, the two Sight Vanes; also let AK be the Index, with *vernier* Divisions (usually called the *Nonius*) at K, to be moved over the graduated Limb BC. (See Fig. of the Quadrant in the *Front Plate*.)

11. Again (in Fig. 1.) Let the Plane or Surface of the Index-Glass D be denoted by ABCD; that of the first Horizon Glass E, by EFGH; and that of the second F, by IKLM. Then it has been shewn, (in the THEORY) that when the Surfaces of the two Glasses ABCD and EFGH are perfectly parallel to each other, the *reflected Rays from the latter will be parallel to the incident Rays on the former*, and consequently, the *Image of any distant Object must appear in the same Place, or coincide with it*. And on this Principle the Adjustment of the Instrument depends, for the *Fore-Observations*.

12. With

12. With respect to the *Back-Observation* the Quadrant is adjusted by making the Plane of the Glass IKLM truly perpendicular to the Plane of the Index Glass ABCD.

13. Now, in regard to the first and principal Adjustment, consisting in the *Parallelism* of the two Glasses ABCD and EFGH, it is self-evident that if two Sides AD and AB in one, be made parallel to the two similar Sides EH and EF in the other, the Surfaces of the Glasses must be thereby rendered parallel, and the Adjustment truly completed. And the same Thing holds good for the *Perpendicularity* of the Surfaces of the two Glasses ABCD and IKLM.

14. Hence it appears that two Operations will be necessary in each Rectification or Adjustment of the Instrument for Use; and for the better Understanding of this, let the Base-lines (or Lines of Position) AD, HE, KI, be continued out to d, b, k , and then the first Part of the *Mechanical Operation* in the Adjustment will be to make the Base AD, or Line of Position Dd , truly parallel to the Base EH, or Line Hb , in the Fore-Observation. And the Base-line Kk truly perpendicular to Dd , in the Back-Observation.

15. The second Part of the Operation of Adjustment, is to render the two Sides AB and EF precisely parallel in the Fore-Observation; and also the Sides AB and IM parallel, in the Back-Observation.

16. Now

16. Now these two Operations or Parts of the Adjustment are, in Quadrants of the common Construction, to be performed on *all the three Glasses*, but in the present *new Construction* they are referred to *one only*, viz. the Index Glass ABCD. And herein we imitate the Simplicity of Nature, who never employs a Multiplicity of Means or Causes, where one alone is sufficient.

17. That the Index Glass alone will answer all the Purposes of Adjustment and Rectification of the Quadrant in the most perfect Degree, and with a most peculiar Facility, will be very evident on a due Consideration of the following Particulars.

18. The first Part of this New Construction consists in *fixing the two Horizon-Glasses* E and F firmly to the Frame of the Octant, so as to be quite incapable of any Sort of Motion at all, since none is required in them by the Theory. Therefore (in Fig. 2.) the Lines of their Bases HE*b*, and KI*k*, are given in Position.

19. In the second Place, the Base Line H*b* of the first Horizon Glass EFGH is nearly parallel to the Side AB of the Quadrant; and the Base Line K*k* of the second Horizon Glass IKLM is *nearly* perpendicular thereto. Also the Plane or Surface of each Glass is *nearly* perpendicular to the Plane of the Instrument. I say (in all these Cases) *nearly*, because the Theory does not require they should be *perfectly so* for the *Rectification* of the Quadrant.

20. In the third Place, the Index Glass D (or ABCD,

ABCD, Fig. 1.) is placed on the Index in a *moveable State*, in two different Respects, *viz.* (1) about an Axis perpendicular to the Plane of the Instrument in the Center of Motion to the Index, and (2) it has a Motion of Inclination to the said Plane on either Side; and *these two Motions* are all that are necessary, for a perfect RECTIFICATION of the Instrument.

21. Then by the first Motion about the Axis, the Base AD of the Index Glass is at any Time made parallel to the Base EH of the Horizon Glass; and by the second Motion of Inclination, the Side AB of the former, is rendered parallel to the Side EF of the latter, and so the Surface of one is of Course parallel to the Surface of the other, and the *Octant is thus duly rectified for the Fore-Observation.*

22. Again, by the first Motion of the Index Glass, its Base AD, or Line Dd is posited perpendicular to the Base Line Kk of the second Horizon Glass; and by the Motion of the Inclination in the former, the proper Adjustment is effected in the latter; and thus the Plane of the Glass ABCD is made truly perpendicular to the Plane of the Glass IKLM; and so *the Instrument is verified for the Back-Observation.*

23. The Effects which these two Motions severally produce in reflex Vision in the Horizon-Glasses E, F, are thus to be understood. In the Theory it has been shewn, that when the Quadrant is truly rectified, and the Index placed at the beginning of
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the Divisions (O) on the Limb BC, then the *incident Rays* (for any Object) on the Index Glass D will be reflected by the Horizon Glass E in a Position perfectly parallel, and consequently the Image seen in the Glass E will appear in the same Place with the Object viewed by direct Vision, or they will both *unite or coincide*. Thus the *Sun* and its Image will both appear as *one Sun* at A, suppose (Fig. 2.) in the Vertical Line FG.

24. But, if the Position DA of the Index Glass be not in a Line Dd truly parallel to the Line of Position Hb, then (other Things remaining the same) the Image of the Sun will appear above the Sun at B, or below it at C (Fig. 2.) that is, if the Position of the Index Glass be not on the Line Dd, it must be in some other, as Da or Db; if it be in Da, the Image will be seen above at B; but if in Db, it appears below at C, in the same Vertical FG. In the case now considered, the Side AB is supposed parallel to the Side EF of the Horizon Glass.

25. On the contrary, if we suppose the Side AD quite parallel to the Side EH, but the Side AB not parallel to EF, then the Image of the Sun at A will appear at D or E, in a Line HI *parallel* to the Horizon, accordingly as the Side AB of the Index Glass is inclined to, or reclines from the Side EF of the Horizon Glass.

26. Lastly, if the Quadrant wants adjusting in both the above Respects, that is, if neither the Line
of

of Position DA be parallel to HE, nor AB perpendicular to EF, then the Solar Image will appear neither in the *Vertical Line* FG, nor in the *Parallel* HI, but in some Place between both, as at M.

27. From the above Account of the Errors of the Instrument, it appears, that they may be wholly corrected by *two Screws only*, with milled Heads to be moved with the *Thumb and Finger*, instead of a troublesome *Screw-Driver*. One of these Screws is placed at the End L of an Alidade MN upon the Index of the Quadrant, and moveable about the same Center with it, as shewn in the *Frontispiece*. It is fixed to the Index on one Part, and works in a Screw upon the Alidade on the other. And the Brass Frame, or Case, containing the Index Glass, being placed upon the Head, or Circular Plate of the Alidade, it is evident, this Glass D can be so moved, by a Touch of this Screw, as to be instantly brought into the Position AD (Fig. 1.) parallel to that of the Horizon Glass E. And thus the Error in the Vertical FG is rectified, (Fig. 2.) or the Image B or C made to fall upon A.

28. The Error in the Parallel HI, is rectified by another Screw of the same Sort, fixed upon a small Pillar OP in the circular Plate of the Alidade MN, just behind the Frame of the Index Glass, and moving in a hollow Screw made in the internal Part of the said Frame, projecting through a Hole in the exterior Part, as represented in the *Frontispiece*. For by touching this Screw, it is plain the Inclination of the said Index Glass is altered, and may, at a

C

Glance

Glance of the Eye, be rendered parallel to that of the Horizon Glass E; and thus the Image D or E is made to coincide with the Sun A.

29. If the Quadrant be erroneous in both Respects, now mentioned, or the Image appears out of the Vertical F G, and parallel H I, as at M (Fig. 2.) then a small Motion of the Screw at N, carries the Image up to the Parallel of the Sun H I, and a Turn of the Screw at P, brings it to fall upon the Sun at A, in its Vertical F G. And the same is to be done for the other Horizon Glass F.

30. From the above Account of this *New Structure and Furniture of the Sea-Octant*, it is very manifest, that at any Time, whether at Land or Sea, if the said Instrument wants adjusting in Whole, or in Part, it is performable almost in a Second, without taking the Eye from the Sight Vane, and, without the least Degree of Trouble; and I would wish to know what the most *indolent* or the most *adroit* Mariner can desire more?

31. And yet, many more Advantages attend this Construction, for it not only fixes the Horizon Glasses E and F in such Manner as to render them Proof almost to Accidence itself; but supposing they should by any Cause have their Positions a little altered or varied, yet this will not concern the Navigator, as the Truth of his Instrument does not depend upon a perpendicular Position of these Glasses to the Plane thereof, as we have before observed (19); and therefore suppose the wooden Frame

to warp, or not to warp, the Case is much the same, since an Error a little encreased, is, in this Way, as easily corrected as if it were not encreased at all.

32. In short, by this Contrivance of *placing all the Correction in one Glass*, the Instrument is, as it were, exempted from any Idea of being erroneous at all, if the Limb of the Quadrant be of a just Extent, and the Divisions accurately true; as all other Faults it can be liable to, are so immediately corrected by the Screws.

33. But a signal Advantage attending this Invention, has not yet been mentioned; *viz.* That when the Instrument is once rectified, it cannot be easily conceived how it is possible (*mechanically speaking*) for it ever to be falsified, or put out of Truth, because when the Index Glass has received its just Position for the Screws at N and P, there is a *brass Cap or Cover* to be screwed over each, that it may not be subject to any Disturbance from any rub, or contact with any other Object, than that of the Mariner's Thumb and Fingers only.

34. The long Continuance of the Rectification of the Quadrant by this *New Improvement*, is further evinced from this Consideration, that as in the usual Construction *all the Glasses are moveable*, here they may be *all considered as fixed*; for the two Horizon Glasses are absolutely rivetted down to the Frame; and the Index Glass, though it be freely moveable by the Screws, yet is it immoveable from any other Cause; for those very Screws which give

it its necessary Motion and Position, do at the same Time prevent *Motion* from any other Cause, and in Conjunction with the strong Pillar OP, at the Back of it, give it the utmost Degree of Firmness and Stability.

35. That which we generally call the ADJUSTMENT of the Quadrant is of a complex Nature; and arises from two distinct Operations, *viz.* (1.) To cause a Coincidence or Union of the Object and its Image in the Vertical Line; or *Circle of the Altitude*, as FG (Fig. 2.) and because in this Case the Image at B or C has a different Altitude above the Horizon from that of the Sun at A, and the Altitude of the Sun A can only be measured by that of its Image at B or C; therefore by making a Coincidence of B or C with A, the Error AB, or AC, is made to vanish by the Screw at N; and this Operation is properly called, *The RECTIFICATION of the Quadrant.*

36. (2.) The other Operation by which the Coincidence of the Image at D or E with the Object at A, in the Parallel of Altitude HI, and is effected by turning the Screw at P, *corrects no Error of the Quadrant*; for there is no Difference in the Height of the Object (or Sun) A, and its Image at D or E; consequently this Part may be called, simply, the ADJUSTMENT of the Quadrant.

37. The first of these Operations is always necessary when the Image of an Object is obliquely situated, as at M; for it must be brought to the

Alma-

Almacantar or Parallel HI, that it may have the same Altitude with the Object A; and then, whether it be adjusted by the Screw P, or not, is not material.

38. From the whole it appears, that the *entire Rectification* of the *Sea-Octant* and *Sextant*, is performed by *one single Screw only*, viz. that at N; which therefore in future we shall call the *Rectifier*, and the other Screw at P, will be called the *Adjuster*. We shall next proceed to some Remarks on the Glasses themselves; their Magnitude, Distance, and other Modifications, which we think not a little faulty and incongruous in Quadrants of the common Construction.

39. Of the various MODIFICATIONS and QUALITIES of the several GLASSES.

For this Purpose, let LCN (Fig. 3.) be the Quadrant; AB the Base of the Index Glass, the middle Point of whose hinder, or silvered Surface, is to be precisely fixed over the Center of Motion C; and the said Glass AB may be nearly coincident with a Line CN drawn from the Center of the Quadrant to (o) or the Beginning of the Degrees on the Limb LMN. We suppose this Glass 2 Inches long, and $1 \frac{3}{10}$ Inch wide.

40. Draw the Line CG, to contain half a right Angle with CM. In this Line CG we give the Position of the Fore-Horizon Glass FD; then a Ray KC in a horizontal Position, falling upon the

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Middle

Middle of the Glas AB, will, after Reflection from C to E, be from thence reflected to the Eye at I in the horizontal Line EI, while the Quadrant is held in a Position (CM) perpendicular to the Horizon.

41. The Distance EI should be at least *six Inches*, for Reasons to be mentioned by and by. In this Case, the Distance CE, between the Index and Horizon-Glas, will be $4\frac{1}{4}$ Inches; continue CE to G, making GE equal to EI, then will CG be $10\frac{1}{4}$ Inches; draw AG and BG; and they will determine the Breadth DF of the Horizon-Glas; for since DF is parallel to AB, it will be CG to EG as AB to DF, that is, $10\frac{1}{4}$ is to 6, as 2 is to $1\frac{1}{3}$, nearly. And in the same Manner the other Dimensions of this, and also those of the Back-Observation Glas, are to be ascertained. N. B. If EI be 5 Inches only, it will, on some Accounts, be better than 6, as we shall see hereafter.

42. With Respect to the Situation of the Back-Observation Glas PQ, let the Line BP be drawn so as to touch the interior Side of the Frame of the Glas DF, which Glas can then intercept no Part of the Light reflected from AB to the Glas PQ placed between BP and the Side of the Octant CL. The Base Lines of these Horizon-Glasses, continued out, must intersect each other in a right Angle DRP, and then its Position will be perpendicular to the Side CN of the Octant, or nearly so, by (22). The Distance of this Glas CQ should

should be full 8 Inches from the Index Glass, that the Head of the Observer, in Back-Observations, may not obstruct the Light.

43. As to what regards the *silvering* and *shading the Glasses*, in this New Quadrant, you will see it for each in Fig. 4. where their Surfaces are represented at D, E, and F, as they stand on the Instrument, and appear to the Eye applied to each, (*abc*) is the upper Part of the Index Glass, and (*fgb*) is the lower Part or Edge on which it stands on the Instrument. The Part (*acde*) is made dark by a black Varnish on the Back-side, that the Solar Rays may be *reflected only* from the first Surface of the said Glass. The Part (*edbf*) is foliated, or quick-silvered on the Back-side; so that the Rays pass from this Part by undergoing *two Refractions* and *one Reflection*. (*bg*) is a black Line drawn through the Middle of the Glass on the back Part, and perpendicular to the Base (*fb*).*

44. The first Horizon Glass E has the Part next the Base (*ilpo*) *silvered*, for the *Reflection* of Light to the Eye; the other Part (*opmn*) is not silvered but left *transparent*, for viewing Objects through it by *direct Vision*. The line (*qk*) is the Appearance or Image of the Line (*gb*) in the Index Glass D.

* This Line (*bg*) is an *Artificial HORIZON* to fit the Quadrant for measuring Angles at Land when required; concerning which, see the DIRECTIONS for the Use of the *Universal OCTANT* in the THEORY of Hadley's QUADRANT.

45. In the Back-Observation Glass F, are three Compartments, *viz.* (*rstv*) which is *silvered* for the Reflection of Light from all Objects, but the Sun. (*tvwx*) a *transparent* Part for the direct View of the Horizon of the Sea, or other Objects; and (*wxyz*) a dark Part for reflecting the Solar Rays received from the dark Part in the Index Glass.

46. The silvered Parts of all these Glasses are to be used for every Object but the Sun, whose Rays being so excessive strong, require two Glasses tinged with a deep, dark Colour, very transparent; and properly placed between the Index Glass D and the two Horizon Glasses, as denoted in the Quadrant at *c*; by which the Rays are so far intercepted and absorbed, that the Eye is not in the least hurt by this Luminary; and hence their Name of *Skreens*.

47. But as the SUN'S IMAGE is the capital Object to be regarded in all Marine Observations, it should be rendered as little confused by a *Variety of Refractions and Reflexions* as possible; and, indeed, the only Way to make the Solar Image most perfect is by *Reflexion only*. In the common Way of observing, there are no less than *eight Refractions* and *two Reflexions*, *viz. ten Operations* of the Glass upon the Rays of Light which form the Sun's Image in the Eye.

48. For the better understanding the Manner in which Light is refracted through the Glasses of the Quadrant,

Quadrant, it is shewn in Fig. 6 and 7. In Fig. 6, let S be the Sun, and AB, CD, two parallel Rays proceeding from it to the Eye at I; one of which, AB, enters the Eye directly without Refraction, but the other CD is incident upon a Glass Body (*abcd*) whose two sides (*ac*) and (*bd*) are truly parallel; then by the *denser Medium of Glass*, the Ray CD is refracted at D into a new Direction DE; and at E in the other Side, it is again refracted into (*a rarer Medium*) the *Air* in another new Direction EF, to the Eye at I.

49. But this Ray EF, is, after the second Refraction, perfectly parallel to the incident Ray CD, and consequently to the other direct Ray AB; and therefore the Eye will perceive the Sun S in the very same Place by each; but if the Sides of the Glass (*ac*) and (*bd*) were not parallel, neither would the Rays AB and EF be parallel, and in that Case, the Sun will appear through the Glass by the refracted Ray EF, in a Place different from its true Place shewn by the unrefracted Ray AB.

50. And from hence appears the Necessity of having all the Glasses contained in this Marine Instrument so truly ground with *parallel Surfaces*; for else the Observations would be *falsified* by exhibiting on the Limb an *Altitude of the Sun different from the True One*; and hence also their Name of *Parallel GLASSES*.

51. Of the various REFRACTIONS and RE-
ELECTIONS of the RAYS of LIGHT, thro'
D the

*the SUBSTANCE and from the SURFACES
of the GLASSES.*

In Fig. 7. are shewn the Refractions and Reflection of a Ray in its Progress through the Index and Horizon Glafs to the Eye; for which purpose the Thickness of those Glaffes (*abcd*) and (*efbi*) is magnified about five or six times. Then let the incident Ray *AB* upon the Index Glafs in the Point *B*, be *refracted* from *B* to the Point *C* in the hinder Surface (*ab*). Here, by the Quicksilver, it is *reflected* back again to *D* in the fore Surface, and from thence it is *refracted* towards the Horizon Glafs (*efib*) but on its Way thither, it passes through the two dark Glaffes (*G, g,*) in each of which it suffers two Refractions (as explained in Fig. 6.) From these it proceeds to *H*, a Point in the fore Surface in the Horizon Glafs (*efbi*); from which it is *refracted* through the same to *I* in the hinder Surface, where it is again *reflected* to *K* in the first Surface, and from thence it is *refracted* (the last Time) into the Air, in a Direction *KL* exactly parallel to that of the incident Ray *AB*. So that the Ray in passing from *A* to *L* suffers *eight Refractions and two Reflections*.

52. In the Point *C* draw the Perpendicular *PC*, and make *PC* to *Po*, as the *Sine of Incidence out of Air into Glafs* is to the *Sine of Refraction*; and thro' the Point (*o*) draw (*mn*) parallel to (*ab*); then will the Ray *DH* have the same Position as if the incident Ray had impinged on the Plane (*mn*) in the Point

Point (*o*), and there been reflected in the Direction (*oH*.) And the like Construction being made in the Horizon Glass, by drawing (*pr*), it is evident, *DH* continued to (*q*), will be reflected from thence in the Direction (*qL*); and therefore the Angle $Aoq = oqL$, shews the refracted Ray *KL* is parallel to the incident Ray *AB*.

53. That the Observation may be perfect in the highest Degree, the Image of the Sun or Moon must be rendered so likewise; and that will be done by forming it by *Reflection* as much as we can, and to admit of the *fewest Refractions*. For Glass being a mixed Substance variously compounded of *Sand*, *Salt*, *Metallic*, and other *heterogeneous Substances*, first fluid, then solid; after that ground, polished, &c. it is no Wonder if from all these Accidents, the Rays of Light in passing so many Times through it, should be in a considerable Degree perturbed and confused; and the Solar Image thereby rendered sensibly imperfect, and ill defined to the View; this we know but too well to be Fact, by Experience.

54. But on the other Hand, could we form the Image of the Sun, or other Objects, by *Reflection only*, then they would be most compleat, and best defined that is possible by Nature or Art; for it is a decided Truth, that the Light never so much as touches the Surface of the reflecting *Speculum*, and consequently can suffer no Irregularities in its Passage to the Eye, nor be contaminated by any Im-

purities of the vitrious Substance which it never enters, and which it never touches.

55. But though it will not be worth while to attempt forming the Image by Reflection alone, yet we can do it by *two Reflections*, and *two Refractions only*, instead of *eight*, in the following Manner. The outer half of the Index Glas (acde) (Fig. 4.) having a black Ground or Lining, absorbs by far the greatest Part of the Light incident upon it, and reflects the small Remainder to the unfiltered Part (mnop) of the first Horizon Glas E; there the Light is again diminished by a great Part being refracted through the Glas, and lost for want of the filtered Surface to reflect it; but even now this second Remainder of the Beam is too strong for the Eye, and therefore requires the Interposition of the faint Glas (g) of the two in Fig. 7, to render the Image easy and distinct to the Eye. And thus *six Refractions of the Eight*, are prevented, and those too, of the worst Sort.

56. All we have said is upon Supposition, that the Sun is viewed through a *serene Sky*; but if it be seen through a Cloud, almost ever so thin, or a Fog, &c. then no dark Glas (g) is necessary, and consequently the Vision of the Sun's Image is then *almost* wholly effected by Reflection.

57. I say *almost*, because there are *two Reflections*, and consequently *two Refractions* which the Rays undergo in this transparent Part of the Glas; for the Beam is partly reflected from the first Surface, and in part from the second, or hinder Surface,
(and

(and that Part of the Beam is also *twice refracted*) and these two Surfaces make two Images of the Sun, which are too sensible not to affect the Sight, and make the Observation imperfect and troublesome.

58. To remedy all which, the upper or outmost Part of each Horizon Glass ought to have a black Ground behind, to prevent any Reflexion of Light from thence, like the Glass F in Fig. 4; the transparent Part in both, should serve only to shew the Objects by *direct Vision*, while their Images are seen in the others, particularly that of the Sun, which (when the Cloud supplies the Place of a dark Glass), is then formed wholly by Reflection; and, as far as I can see, in the most perfect Manner that can be contrived.

59. Another Part in which these Quadrants are very deficient, is the Sight-Vane H (Fig. 5.) which for the Fore-Observation Glass E has but two Holes (*a, c,*) instead of three (*a, b, c.*) The first Hole (*a*) should be nearly opposite the middle Point of the silvered Part (*ilpo*), and the third Hole (*c*) opposite the Middle of the transparent Part (*mnop*); but the middle Hole should be nicely opposite to (*q*) the middle Point of the Limiting Line (*op*), for then this Line will appear very fine and slender, as it ought to do in setting the Quadrant by the Sun, which is the principal Operation. But this bounding Line through the Hole (*a*) or (*c*) appears too gross for the nice Purpose of observing the Contact of the circular Limbs of the Sun and its Image,

or

or of the Sun and Moon in Observations of their Distance, for *finding the Longitude*.

60. The Quadrant for the Fore-Observation is rectified as above directed, by the SUN, the MOON, a PLANET, a STAR of the first Magnitude, or, in short, any distant terrestrial Object (not nearer than half a Mile), the Method of doing which every Mariner knows full well; but as that by the Sun is preferable to all others, and the most perfect, if made by *Reflection only*, from the dark Speculums, (as we have said before) in this Case it will be necessary to have a Piece of thin Brass to be turned up, and compleatly cover the silvered Part (*edfb*, Fig. 4.) of the Index Glass D. This Blind keeps its Position when up or down by the Resort of an easy Spring.

61. Also two small Pieces of Glass are applied behind the transparent Part (*nmop*) of the first Horizon Glass E, one of which is very dark for the SUN seen by *direct Vision*; and the other a green Glass for the viewing the *Moon, Planet, or Star*, by taking off the Glare which attends the Vision of these Objects by the naked Eye.

62. The METHOD of RECTIFYING the OCTANT for the BACK-OBSERVATIONS.

The Manner of *adjusting and rectifying* the Octant for the *Fore-Observations* having been sufficiently particularized; it remains now to shew how the same

same Things are effected for the *Back-Observation*. Here, indeed, we are confined to *one Object only*, but, in this new Construction, that *one* is enough to answer the Purpose compleatly. The *Marine Horizon* is the Object I mean, no other admitting a Conjunction with its Image, in the Point of Opposition.

63. To make this Matter evident, first for the *Adjustment*, let ADE be the said Horizon of the Sea (Fig. 8.) in which the Eye possesses the Center C, and let AB be an Arch or Part thereof seen through the transparent Part (*tvwx*, Fig. 4.) of the Glafs F. Then if the Side AB of the Index Glafs (Fig. 1.) and the Side IM of this Back Observation Glafs were parallel to each other, the Image of the opposite Part (*ab*) exactly coincides with AB, and they both make *one Line* (when the *Dip of the Sea* on each Side is allowed for,) and the Instrument is rightly adjusted.

64. But when the said two Sides AB and IM are not parallel, then some other Part as (*ac*) or (*bd*) will join AB in one right Line, but that will occasion no Error in the Quadrant, as it makes no Difference in the Position of the Horizon AB. It is therefore of no Consequence whether this Glafs F be adjusted or not, and since the Parts of the Horizon (*ab, ac, bd*) cannot be distinguished one from another, it will, indeed, be impossible to adjust it at all.

65. The

65. The *Rectification* of this Glass is therefore only to be attended to, and is certainly of great Importance in the Affair of finding the Longitude and Latitude; but in order to its being well understood, what relates to the *Double Dip* of the Sea must be first explained. Let AB be the Height of the Eye above the Convex Surface of the Ocean CBD (Fig. 9.) and suppose AE, AF, two visual Rays touching the Sea, in the Points E and F, which will be in the Marine Horizon to the Eye at A. Through A draw GH perpendicular to AB, and it will represent the *True Horizon*; continue EA to I, and draw IF, GE, perpendicular to GH; then on one Side the Dip of the Sea is GE, and on the other Side it is HF; and both together, or the *Double Dip* on the same Side will be IF or the Angle IAF.

66. Now because the Horizon at E, seen in this Glass, appears in a right Line opposite to it at I, and because by the backward Motion of the Index, all Objects appear to move *downwards* in this Glass, therefore if the Index be moved so far back, or to the right Hand from (O) as is equal to twice the Dip of the Sea, it is plain, the apparent Horizon at I will descend to, and coincide with the Horizon at F, and both appear as one curve Line, if the Glass be already rectified.

67. But if when the Index has been moved backwards its just Quantity, the Horizon at I does not exactly coincide with that at E, but appears
either

either above or below it, it shews that the Angle IAF is not truly measured by it, and that therefore no other *Angle of Altitude or Distance* can be shewn truly by the Instrument in such a Case.

68. If the Point I, or reflected Horizon in the Glass, appear at (*a*) above the real Horizon F seen through the Slit, then the *Error is in Excess*, and the Index must be put farther Back (than *Double the Dip*) to make a Coincidence of the apparent and real Horizon. But if when the Index is moved back from (O) through an Arch equal to the Double Dip IAF, the Horizon I by Reflection, appears below the true Horizon F, as at (*b*), then the *Error will be in Defect*, or there will be a Coincidence of I and F, with a less Number of Minutes than is just.

69. The Error *aAF*, or *bAF*, being once nicely measured by the *Vernier* on the Index, will, in this new Construction of the Quadrant or Sextant, be constant or always the same, because the Back-Observation Glass is fixed. And therefore this Error, if in *Excess*, must be *subtracted*, if in *Defect*, must be *added* to the Angles of Altitude, Distance, &c. taken by the Instrument. But this Glass is so critically adjusted and rectified by a *Fore-Observation* of the Sun, and by that Means fixed in a *just and permanent Position*, that I may venture to affirm the above-mentioned Error will be *very rarely (if ever) sensible*, in these *New Quadrants*.

70. The Error of the Octant, which we have been speaking of, will be the same in *Quantity*, but

E

of

of a different *Quality* both in the Fore and Back-Observation, as the Index moves *forwards*, or from (O) to 90 on the Limb; or *backwards* from (O) to the right Hand: In the first Case the Motion of the Image is *direct*, and in the latter, it is *retrograde*. Thus in measuring the Angle IAF, the Motion of the Index is *backward*, the Motion of the Image of the Sun, Horizon, &c. is *retrograde* from I to F; and the Error aF is in *Excess*, and *subtrahive*.

71. But if on the contrary, the Image of an Object appears below the Horizon at L, then by moving the Index *forward* from (O) towards 90, the Motion of the Image will be *direct*, ascending from L to F; but the Error bF (equal to aF) will now be in *defect*, and is to be *added* to the Angle shewn by the Index. These are the Circumstances of the Error in the *Back-Observation*.

72. In the Fore-Observation the very same Properties of the Error will happen, which may be thus illustrated; let it be required to measure the Distance AB between two Stars A and B, (Fig. 10.) If the Octant be truly rectified, when (O) on the *Vernier* is placed exactly at (O) on the Limb, the Images of the Stars will unite with the Stars themselves, and they will each appear as one Star; and by moving the Index forwards, the Image of A will directly move to B (seen in the transparent Part of the first Horizon Glass) and the Degrees and Minutes

minutes shewn on the Limb by the *Vernier* will be the true Distance of the Stars. (See THEORY of Hadley's QUADRANT.)

73. But if when (O) on the *Vernier* stands at (O) on the Limb, the Image of the Star A be at (a) then Aa will be the Error of the Octant; and when the Index is moved from (O) towards 90, the Image (a) descends to B, and the Angle measured, or shewn on the Limb, is the apparent Distance aB, less than the True by Aa, the Error in Defect, which therefore is to be added to the measured Angle, and it will give the true Distance AB.

74. If the Distance of the Stars exceed not the Number of Degrees to the right Hand of (o) on the Limb, then it may be measured by the *retrograde Motion* of the Index that Way, taking the Image (b) of the Star B for that Purpose; for as the Index goes *backward* the Image (b) will *retrograde* or ascend to the Star A; and the apparent Distance of the Stars will now be bA, greater than the true Distance by the Error in Excess Bb, which therefore is now to be subducted from the measured Distance bA, to have the true Distance AB. Note, Had the Images (a) and (b) fallen above A, and B, then the Error aB would have been in Excess, and bB in Defect.

75. In like Manner you find the Quantity of the Error by measuring the Diameter of any distant Object on Land or in the Heavens, where the Sun and Moon offer themselves as the fittest of all others: For let AB be the Diameter of the Sun in the Ver-

tical Xx (Fig. 11.) and (ab) that of its Image depressed (by the *Error in Defect*) from A to a , when (O) in the Index stands at (O) on the Limb.

76. Now to find the Diameter of the Sun AB and the Quantity of the Error Aa , you move the Index *forwards* on the Limb till the upper Part of the Image (a) comes to touch the lowest Limb of the Luminary in B , as represented in the Vertical Yy ; and suppose this Descent through aB be $29'$.

77. Then replace the Index to (O) on the Limb, and move it from thence *backwards*, till the lower Part of the Image (b) comes in Contact with the upper Part of the Sun or Moon at A , as shewn in the Vertical Zz ; and if it shews $32'$ in measuring this Motion from (b) to A (in the Vertical Xx) Then it is evident, that $29' = aB$ subtracted from $32' = Ab$, will leave $3'$ for the Sum of Aa and Bb , or twice Aa ; therefore the Value of the Error Aa is $1' 30''$ which added to $29'$, make $30' 30''$ the true Measure of AB , or the SUN'S DIAMETER.

78. It is to be observed, that in counting the Minutes of a Degree by the *Vernier*, in the Backward Motion of the Index, the Number 15 is to be considered as 5 ; and on the other Side, the Number 5 is to be read 15 ; the Reason is evident, for as the *Degrees* are now on the right Hand of (O) so the *Minutes* are reckoned to the left Hand of the *Degrees*; just contrary to the Reckoning when the Index moves the usual Way *forwards*.

79. The

79. *The NATURE and DIFFERENCE of the Fore and Back OBSERVATION considered, as made by one and the same HORIZON GLASS.*

As a further Illustration of the Nature and Difference of a *Fore and Back Observation*, let us consider them as made by one and the same Horizon Glass, moveable into different Positions. Thus (Fig. 12.) let NCL be the Octant, AB the Index-Glass, and DF the Horizon Glass in the Position DP parallel to AB; on the Center thereof E describe the Circle ZHXO, and draw the Horizon HEO. Let KC be a Solar Ray incident on the Glass AB, from thence reflected to E, and from thence to the Eye at I. Now the Index being fixed at (O), by the Rectifier at N (on the *Alidade*) the Sun S and its Image T, are brought either to coincide, or to be in the same Almacanter (as we have said before) and thus the Quadrant is rectified.

80. Then to make an Observation of the Sun's Altitude, let (b) and (a) represent the Edge of the Sea at the Sky. And move the Index forward from N to M till the Sun's lower Limb touch the Sea at (b), then the Arch Sb described by the Image of the Sun is double the Angle NCM shewn on the Limb of the Quadrant, and when the *Dip of the Sea*, and *Refraction*, are subducted from it, there will remain the True Altitude SH of the Sun's lower Limb above the Horizon.

81. But

81. But now upon Supposition that the Marine Horizon at (*b*) under the Sun *S* is *not visible or distinct*, but the opposite Part at (*O*) is so; then, by turning the Glafs from the Position *DF* to *Gg*, so that *FEG* (or *PER*) may be exactly a *Right Angle*, the Ray *CE* will now be reflected just in an opposite Direction, to the Eye at (*i*); and the Image of the Sun *S* will appear precisely in the Point of Opposition at *Q*; and the Index being moved forward from (*O*) to (*m*) on the Limb, will cause the Image to rise from *A* to the Horizon of the Sea at (*o*); and if from the Arch *Qo* you deduct the Refraction agreeing thereto on one Hand, and on the other, you add the Dip of the Sea *Oo*, you will have the Arch *QO* exactly equal to the Arch *SH*, or Altitude of the Sun above the Horizon, as before.

82. By the Motion of the Horizon Glafs from its Situation *DF* to *dg*, it is evident, the visual or reflected Ray *Ee* has described the Semi-circle *eGD i*, in which had the Eye been carried, it would have seen the Solar Image describe the Semi-circle *SHPQ*.

83. As in this Position of the Horizon Glafs *Gg*, the Motion of the Index from *N* towards *L* makes the Image move from *Q* towards *O*; so on the contrary, the Index being moved from *N* towards *V* will cause the Image at *Q* to *retrograde* from *Q* towards *P*; and if *NV* be equal to 30 *Nautical Degrees* (such as on the Limb of the Quadrant), then the Angle *LCV* will be 120, and

and the *Retrogradation* of the Image will, therefore, be 30 Degrees in the Sextant L C V.

84. But it will be necessary to have Recourse to Fig. 13. to explain what relates to the *Fore and Back-Observations* jointly, and in general, wherein A H E O is the Horizon, and B H D O an oblique *great Circle* passing thro' the Sun S, and the Moon at M, F, *m*. Now it is evident, (1.) That any Distance of the Moon from the Sun, in her *first Quarter*, is measurable by the *Fore-Observation*. (2.) That while the Moon is in the second Quarter, as at (*a*), her Distance from the Sun is known by the *Back-Observation*; for by that you have her Image at (*b*) in the last Quarter, (diametrically opposite to (*a*);) then by moving the Index forwards from (O), the Image will be carried through *b* S, which Arch is measured by the Degrees on the Limb, and being equal to *a* F, will, when subtracted from 180° , leave her Distance S *a* from the Sun as required. (3.) The Distance of the Moon from the Sun in the third Quarter, as at D, is measured also by the *Back-Observation*; for the Image of the Sun at F is then carried to the Moon at D, and the Arch F D thus measured, and taken from 180° , leaves the Distance D S required. (4.) The Moon in the last Quarter, as at (*b*), has her Distance *b* S measured by the *Fore-Observation*, as being less than 90° .

85. The *Sextant* measures Angles by the *Fore-Observations* only to 120 Degrees as from S to (*a*). Mr. C. *Smith* made an excellent Instrument to measure Angles to 150° , by the *Fore-Observation*; and a REAL QUADRANT may be furnished with two
Glasses

Glasses only, in such a Situation as to measure Angles on each Side a given Object to 170 Degrees, or 340° upon the Whole, by a Motion of the Index once over the Limb; and a greater Extent than this cannot be given, by reason the Index-Glass is, at last, too much *fore-shortened in its Reflection from the other*.

86. *A DEMONSTRATION of the whole THEORY of the SEA-OCTANT in Four Lines only.*

I observed at the Beginning, that though no Instrument can compare with the Sea-Octant for Usefulness, yet none has so concise and perspicuous a Theory, which I shall now demonstrate (from Fig. 14.) may be contained in *four Lines only*. For let LCN be the Octant, AB the Index-Glass, DF the Horizon Glass, parallel to CN; HO is the Horizon, pCQ a Perpendicular to the Glass AB; EQ a Perpendicular to the Glass DF; S is the Sun, SC the incident Ray, CE and EI, the same twice reflected; produce SC to intersect EI at I, the Place of the Eye.

87. When the Index is at (O) on the Limb, since then the two Glasses AB and DF are parallel, their Perpendiculars will be parallel also; but if the Index be moved to X, it will make an Angle NCX equal to that made by the Perpendiculars, *viz.* pQE . Now it is to be shewn, that the Angle of the Sun's Altitude SCH or SIE is double the Angle NCX (or pQE), which makes the Sun appear in the Horizon at H.

Thus

Thus - $2 SCp = SCE = 2 CEQ + CIE.$

Therefore $SCp - CEQ = \frac{1}{2} CIE.$

But - $CEQ = pCE - CQE.$

Therefore $SCp - pCE + CQC = \frac{1}{2} CIE = CQE.$

Q. E. D.

90. It is further evident, that however the Octant may be moved in the *Vertical Plane* passing through the Sun, yet will the Ray EI be always *parallel to itself*, and constantly *shew the Image of the Sun at Rest in the Horizon*, for the Motion of the Image results from nothing but the Motion of the Index over the Limb LMN.

91. *Of the several STEPS that are to be taken in finding the LONGITUDE at SEA, by the observed DISTANCE of the MOON from the SUN.*

Step 1. At a known Time by the Watch, let the *Altitudes of the Centers of the Sun and Moon*, and the *Distance of their nearest Limbs* be determined from a *Mean of (at least) three Observations*.

92. Step 2. To find the apparent Time at the Ship, another Observation is made (soon after the first) of the Altitude of the Sun's lowest Limb, and from thence, of his Center E; the Complement of which is his *Zenith Distance ZE* (in Fig. 15.)

93. Step 3. Let the *Longitude for Greenwich* by the Ship's Reckoning be *turned into Time*, by the proper Table for that Purpose, and *added to*, or *deducted from* the Time of the Observation, as the

F

Ship

Ship is *West* or *East* of the Meridian of *Greenwich*; then will the *apparent Time at the Observatory* be thereby obtained, nearly.

94. Step 4. The SUN'S DECLINATION EK is found for the Noon of the foregoing Day by the *Nautical EPHEMERIS*; and by the Diurnal Variation thereof, you find it by the Rule of Three, for the present Hour and Minute. Then the *Co-Declination* PE is obtained.

95. Step v. The Latitude AZ of the Ship is known by the Account carried on from the foregoing Noon; and therefore the *Co-Latitude* PZ.

96. Step vi. By this Process the three Sides ZE, PE, and PZ, of the oblique spherical Triangle EPZ, are known; from whence (by the *Common Canon of Logarithms*) you find the Hour Angle at the Pole P, or APK, which gives the *Time apparent from Noon* (or *Midnight*) by Calculation; and by comparing the Time shewn by the Watch with the Time now found, the Difference will shew how much the Watch is *too fast* or *too slow*.

97. Step vii. The Error of the Watch thus found being *added to*, or *subducted from* the Time of the first Observation, will give the *apparent Time thereof correct*.

98. Step viii. Let Fig. 16. represent the first Observation, viz. AZ the Vertical of the Sun at S, HZO the Vertical passing through the Moon at M, and MS the observed Distance of the nearest Limbs of these Luminaries; then the Azimuth or Angle AZO is to be found thus. The Semi-diameter of the Sun at the Time is known from the
Epbemeris

Ephemeris, which added to the Altitude of his lower Limb, gives the Altitude of his Center AS, Allowance being made for the *Dip of the Sea*, therefore the Co-altitude SZ is known.

99. Step ix. In like Manner the Semi-diameter of the Moon is found in the said *Ephemeris*, and being encreased by a few Seconds from a small Table, is added to the Altitude of her lowest Limb (allowing for the *Dip*) gives the apparent Altitude of her Center MO above the Horizon HO; and therefore also her Co-Altitude, or Zenith Distance ZM.

100. Step x. To the observed Distance of the nearest Limbs of the Sun and Moon add the Sum of their Semi-diameters, and you will have the apparent Distance of their Centers SM.

101. Step xi. Having thus obtained the three Sides of the oblique spherical Triangle SZM you find the Angle at Z, or Azimuth SZM, by the same *Theorem* (as before) and *logarithmic Canon*.

102. Step xii. From the *observed* Altitudes and Distance of the Centers of the Sun and Moon, you find the *True* in the following Manner. From the observed Altitude of the Sun's Center AS subtract the *Refraction* (agreeing thereto in the Table) and the Remainder will be the *true Altitude* As, and the Zenith Distance Zs.

103. Step xiii. From the observed Altitude of the Moon's Center deduct the *Refraction* agreeing thereto in the Table; and to that Remainder add the *Parallax* found in the *Ephemeris* (for the given Time) properly corrected, the Sum will be the true Altitude Om; and Zenith Distance Zm.

104. Step xiv. Through (m) and (s) draw the Arch of a great Circle ms , which is the *true Distance* of the Centers of the Sun and Moon, and is found by the Triangle sZm , in which there are known the Sides Zs , and Zm , and the included Angle at Z , by Step xith. In this Process the same Theorem is used as in the above.

105. Step xv. The Time at Greenwich is now to be found when the Distance of the Centers was (sm) and for that Purpose the true Distances of the Centers of the Sun and Moon are calculated in the Ephemeris for every third Hour of the Day, throughout the Year. Your given Distance will therefore fall between *some two* of these, which are to be sought out.

106. Step xvi. Call the preceding Distance A , and the following one B , and your Distance (sm) between them, C ; then make this Proportion; *As the Difference between A and B is to the Difference between C and A , so is the Interval of three Hours to the Time between the Times of A and C , which added to the Time of A , gives the Time of C , or the Time at Greenwich, when the Distance of the Centers was (sm).* But the Time at the Ship is also known, (Step vii.) Consequently the Difference of Time at the Ship and the Observatory being turned into Motion, will give the *Arch of the Equator between their Meridians*, which is the LONGITUDE required to be found.

107. Every Step of this Process, is natural, clear and easy; contains nothing superfluous, or foreign
to

to the Purpose; requires only a few short *Tables*; no Skill in *Algebra* or *Fluxions*, or any uncommon *mathematical Calculations*; and the whole is performed without any Regard to that amazing *Farrago* of pretended *requisite Tables*, which make the second Part of the *Nautical Almanac*, and of another Volume larger than a *Church Bible*; all which the Reader may be fully satisfied of, by consulting the MARINER'S MIRROR, Part ii. where the whole Process is exemplified at large, and agrees within a *second* or two, with the same Case wrought in the *Ephemeris*.

108. All the *Tables* necessary for this Purpose are the following, *viz.* (1) A TABLE of the *Height of the Eye*, and *Dip* of the Sea. (2.) A TABLE of *Altitudes* and *Refractions*. (3.) A TABLE of *Seconds* for correcting the *Moon's Altitude*. (4.) A TABLE of *Altitudes* and *Parallaxes* for the *Moon*. (5.) A TABLE for converting *Time* into *Motion* of the *Equator*. (6.) A TABLE for turning *Motion* into *Time*. These six *Tables* require no more than *four Pages*, and are to be found in the THEORY of *Hadley's QUADRANT*, the MARINER'S MIRROR, and, *Nautical ALMANAC*.

N. B. The 17th Figure in the last Plate was intended for an Illustration of a Subject relative to these Matters, but as it proved too prolix for this Tract, it must be reserved as an Appendix thereto, if Life and Health permit.

A D V E R T I S E M E N T.

*The Prices of the Patent Octants and Sextants are
as follow, viz.*

	£.	s.	d.
O CTANTS, in Mahogany Frames with Vernier Divisions, for double Observations, - - - - -	2	16	0
Ditto, single Observation - - - - -	2	12	6
In Ebony, double Observation, very best Work, and Apparatus - - - - -	3	13	6
Ditto, a plainer Sort - - - - -	3	3	0
A SEXTANT in Mahogany, of the best Work	5	15	6
Ditto, in Ebony - - - - -	6	6	0

N. B. Octants and Sextants of the usual Form,
are altered to this *New Improvement*, at ONE
GUINEA each.

A L S O,

The new-improved <i>Azimuth</i> COMPASS, } every Way compleat - - - - -	3	3	0
A steering Compass, on the same Prin- } ciple, very exact - - - - -	1	16	0

Ditto, a small Size for Boats, of various Sizes

N. B. These Compasses have Agate-capped
Needles; have been proved in long Voyages; and
have the Approbation of the best Judges.



Fig. 1.

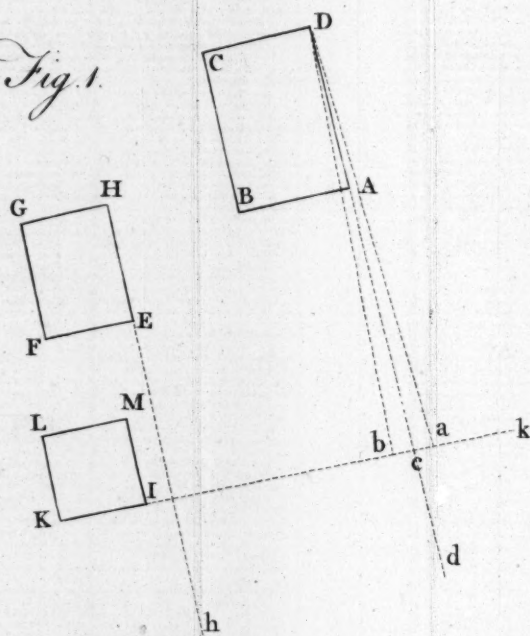


Fig. 2.

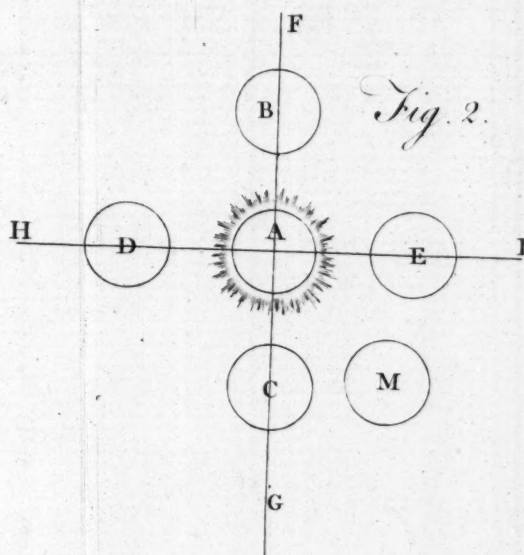


Fig. 3.

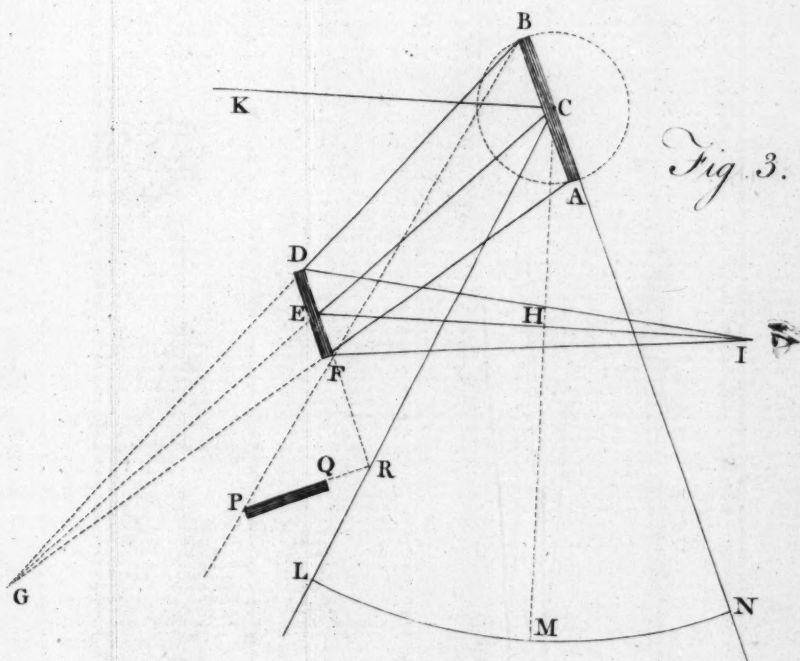


Fig. 5.



Fig. 4.

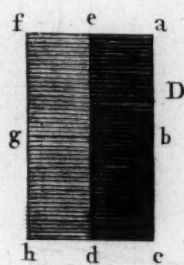
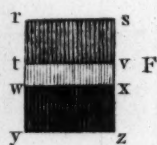


Fig. 7.

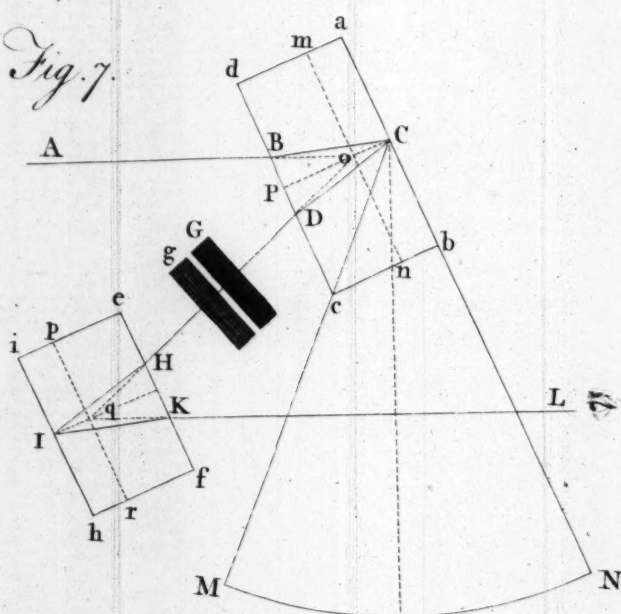


Fig. 8.

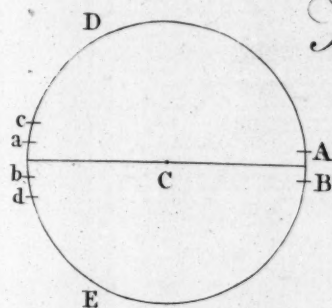


Fig. 9.

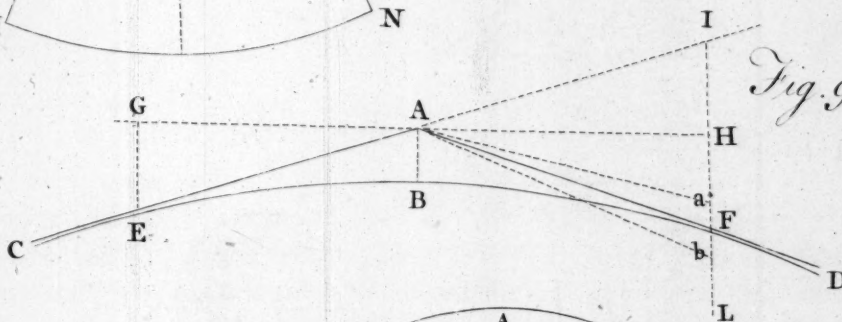


Fig. 6.

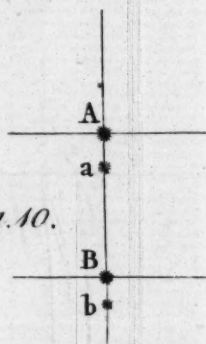
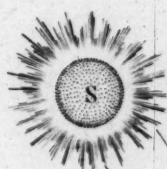


Fig. 10.

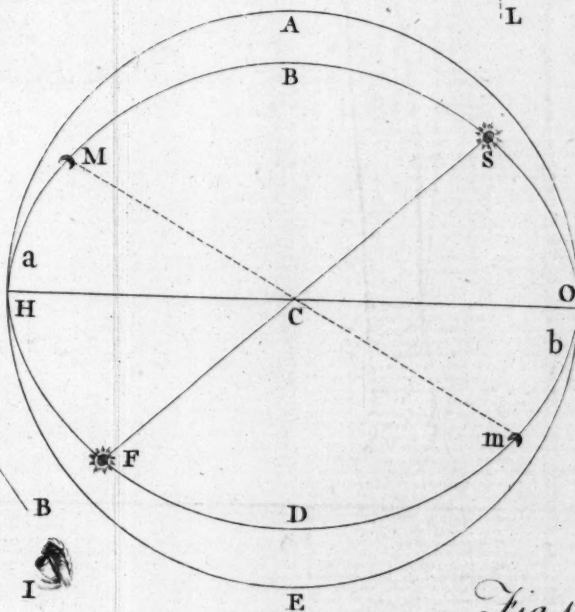
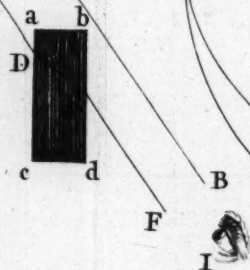


Fig. 13.

